Unit - IV Particle physics

1) Discuss about different types of force's possible in nature, with their chareetaristics?

→ There are four types of fundamental interaction or forces possible in nature.

(i) Gravitational force:- The main chereetaristic's of gravitational force (a) It's depend on the distance between two particle.

(b) It's independent of medium.

(c) the range of the gravitational force is infinite.

(d) It's independent of velocity.

(e) exchange particle in this interaction is graviton [Graviton is not detected practically till now.

(ii) Electromagnetic interaction:- The main characteristics of electro magnetic interaction.

(a) it's depend on distance between two charge.

(b) it's depend on the medium.

(c) the range of this interaction is infinite.

(d) It's independent of velocity.

(e) the exchange particle in this interaction is Photon.

(iii) Strong / Nuclear force :- the main characteristics of nuclear force -

(a) It's independent of charge of the particle.

(b) Nuclear force is short range force, it's act with in the nucleus.

(c) Nuclear force depends on velocity

(d) the Exchange particle in nuclear force is meson (for nucleon - neuleon interaction) and gluon (for higher interaction like anti quark's and quark Interaction).

(iv) Weak force / Weak interaction :- the main chaneeteristic's of weak force -

(a) This type of force mainly involve in nuclear decay like α-distisintegration, β-disintegration, γ-disintegration.

(b) the exchange particle of weak force is gauge boson.

$$f_{nuclear} > f_{electromagnetic} > f_{weak} > f_{Gravitation}$$

(*) classified Particles on the basis of statistical distribution?

→ On the basis of statistical distribution there are two type of Particle — (i) Boson. (They obey Bose-Einstein Distribution)

this Particle has spin integer multiple of $\hbar$. Possible spin of Bosons: $0, \hbar, 2\hbar, 3\hbar, 4\hbar, \ldots$

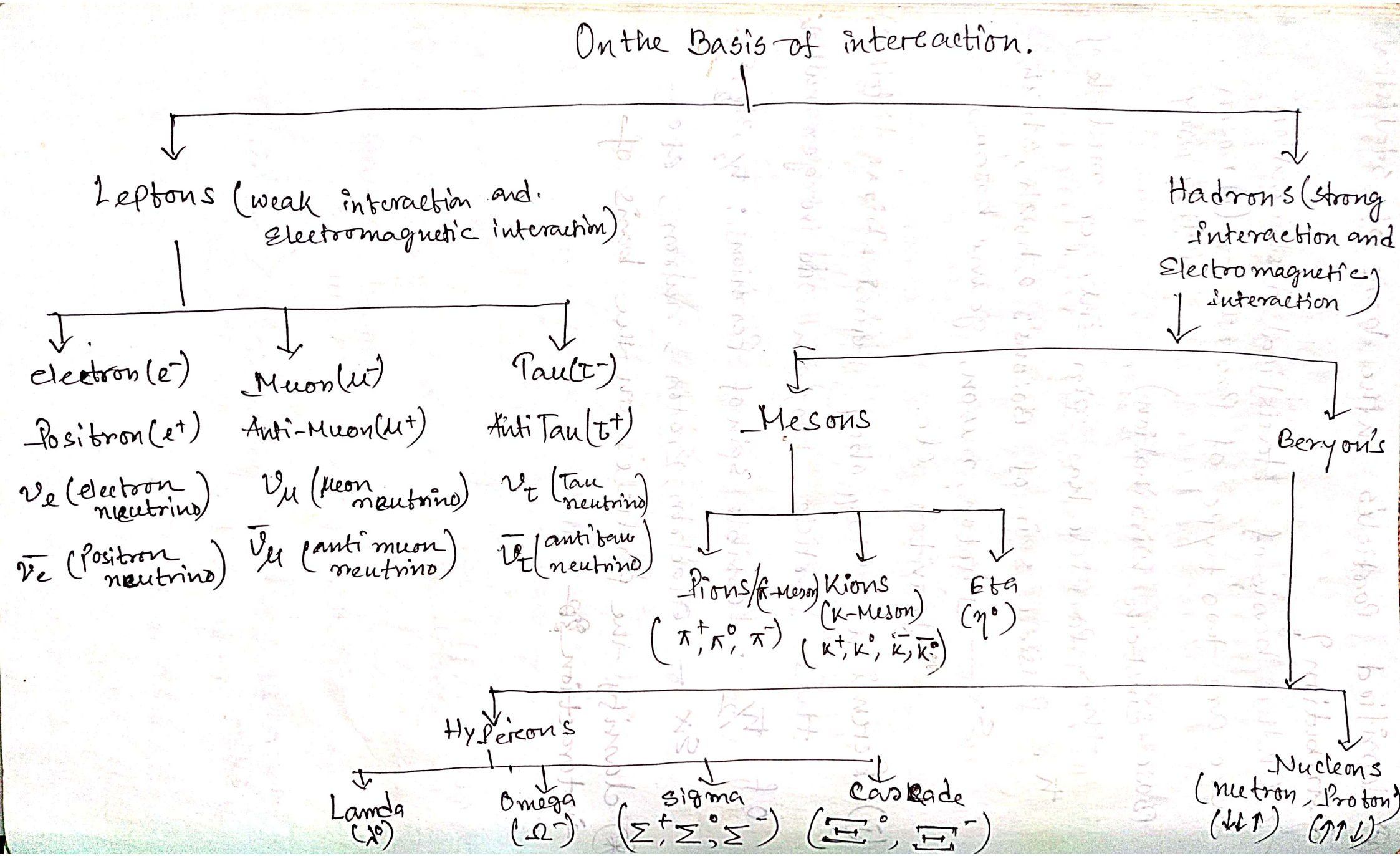
Ex — Photon, meson, gause boson, graviton etc.

(ii) Fermions (They obey Fermi-Dirac distribution)

thes Particle has spin odd integer multiple of $\hbar/2$. Possible spin of fermions: $\hbar/2, 3\hbar/2, 5\hbar/2, \ldots$

Ex — electron, Proton, nutron, etc.

(*) classify the particle's on the basis of interaction?


On the Basis of interaction.
Leptons (weak interaction and electromagnetic interaction)
Hadrons (strong interaction and Electromagnetic interaction)
electron (e^-)
Positron (e^+)
ν_e (electron neutrino)
$\bar{\nu}_e$ (Positron neutrino)
Muon (μ^-)
Anti-Muon (μ^+)
ν_μ (muon neutrino)
$\bar{\nu}_\mu$ (anti muon neutrino)
Tau (τ^-)
Anti Tau (τ^+)
ν_τ (Tau neutrino)
$\bar{\nu}_\tau$ (anti tau neutrino)
Mesons
Baryons
Pions (π-Meson) (π^+, π^0, π^-)
Kions (K-Meson) ($K^+, K^0, \bar{K}^-, \bar{K}^0$)
Eta (η^0)
Hyperons
Nucleons (neutron, Proton) ($\uparrow\downarrow$) ($\uparrow\uparrow\downarrow$)
Lamda (Λ^0)
Omega (Ω^-)
Sigma ($\Sigma^+, \Sigma^0, \Sigma^-$)
Cascade (Ξ^0, Ξ^-)

Note :-

(i) Lapton's and Baryon's are fermion's but Meson's are boson Particle.

(ii) Lapton's Particle's Perticipating E-M interaction and weak Interaction but, do not Perticipating strong interaction

(iii) Hadron's Particle's Participating strong interaction and E-M interaction but- donot Participate in weak interaction.

(*)(i) Write down the conservation law's of any interaction.

ii) Wribe down the approximate conservation law's in any interaction?

→(i) the exact conservation law's are —

(a) mass - energy conservation.

(b) momentum conservation (linear and angular momentum)

(c) charge conservation (Electronic charge conservation, baryonic charge conservation, Leptonic charge conservation).

(d) Baryon no. conservation, Lepton no. conservation.

(e) CPT (charge, Parity, Time reversal)

-this conservation law's must be hold in any natural process or nuclear reaction, if any of the conservation law's is violated, then, the interaction is imposible, that's why they are called exact ~~differ~~ conservation law's.

(ii) Approximate conservation law's:-

(a) Iso spin.

(b) I_3 or Third component of Isospin.

(c) Strangeness(S)

(d) hyper charge (Y)

this conservation law's may or maynot be followed by an interaction. But for strong Interaction ~~and~~ or E-M Interaction, this conservation law's must be hold.

Note:- Lepton number, L = 1 for Lepton

~~Leptons~~

L = -1 for anti Leptons

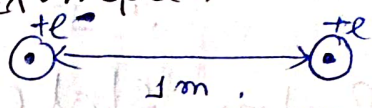
L = 0 for other particle.

Berjon's number, B = 1 for Beryons

= -1 for anti Beryons

= 0 for other Particles.

(*) Compare between the strength of gravitational force and E-M force with an example?



→ Gravitational force, $f_g = G\frac{m_1 m_2}{r^2}$ $\quad m_p = 1.67\times10^{-27}$kg.

$= \frac{6.67\times10^{-11}\times(1.67\times10^{-27})^2}{1^2}$ $\quad r = 1$m.

$= 18.60\times10^{-65}$ N. $\quad$ Charge of proton $= 1.6\times10^{-9}$C

Electrostatic force, $F_E = \frac{1}{4\pi\epsilon_0}\cdot\frac{q_1 q_2}{r^2}$

$= 9\times10^9\times\frac{(1.6\times10^{-19})^2}{1^2}$

$= 23.04\times10^{-29}$

(*) Define Isospin and Third component of Iso-spin.

→ Isospin is an abstract quantity, it is not physical quantity. In strong interaction bet^n two particle's is independent charge. To distinguish between neutron-proton we consider a quantum number, i.e. known as isospin.

Iso-spin is only considered for hedron particles.

If iso-spin of a particle is I, then its third component of isospin has possible value $-I \le I_3 \le I$.

Isospin of two particle can be added vectorically but third component of Isospin is added algebrically.

Example:- Nucleons (proton-neutron) are doubled. ∴ Iso-spin, $2I+1 = 2 \Rightarrow I = \frac{1}{2}$

For 3rd component, $-\frac{1}{2} \leq I_3 \leq \frac{1}{2}$

$\therefore I_3 = -\frac{1}{2}, \frac{1}{2}$.

Proton state $\rightarrow |\frac{1}{2}, \frac{1}{2}\rangle$

neutron " $\rightarrow |\frac{1}{2}, -\frac{1}{2}\rangle$

Note :- Meson - π-meson

$2I+1 = 3$ i.e. $I = 1$

$-1 \leq I_3 \leq 1$

$\therefore I_3 = -1, 0, 1$

$\pi^+ \longrightarrow |1, 1\rangle$, $\pi^0 \rightarrow |1, 0\rangle$, $\pi^- \longrightarrow |1, -1\rangle$

K-Meson

(K^+, K^0) | $(K^-, \overline{K^0})$

$2I + 1 = 2$ | $2I + 1 = 2$

$\therefore I = \frac{1}{2}$ | $\therefore I = \frac{1}{2}$

$-\frac{1}{2} \leq I_3 \leq \frac{1}{2}$ | $-\frac{1}{2} \leq I_3 \leq \frac{1}{2}$

$I_3 = -\frac{1}{2}, \frac{1}{2}$ | $\overline{K^0} \longrightarrow |\frac{1}{2}, \frac{1}{2}\rangle$

$\therefore K^+ \longrightarrow |\frac{1}{2}, \frac{1}{2}\rangle$ | $K^- \longrightarrow |\frac{1}{2}, -\frac{1}{2}\rangle$

$K^0 \longrightarrow |\frac{1}{2}, -\frac{1}{2}\rangle$

Eta (η)

$2I + 1 = 1$

$\therefore I = 0$

$\therefore I_3 = 0$ $\quad \eta \longrightarrow |0, 0\rangle$

Sigma

$2I + 1 = 3$ $\quad I_3 = -1, 0, 1$

$\therefore I = 1$ $\quad \Sigma^+ \rightarrow |1, 1\rangle$, $\Sigma^- \rightarrow |1, -1\rangle$

$-1 \leq I_3 \leq 1$ $\quad \Sigma^0 \rightarrow |1, 0\rangle$,

Cascade

$2I+1 = 2 \quad -\frac{1}{2} \le I_3 \le \frac{1}{2}$

$\therefore I = \frac{1}{2} \quad \therefore I_3 = \pm\frac{1}{2}$

$\Xi^0 \longrightarrow |\frac{1}{2}, \frac{1}{2}\rangle$, $\Xi^- \longrightarrow |\frac{1}{2}, -\frac{1}{2}\rangle$

Omega

$2I+1 = 4$

$\therefore I = 0$

$\therefore I_3 = 0$

$\Omega^- \longrightarrow |0, 0\rangle$

Lambda

$2I+1 = 1$

$\therefore I = 0$

$I_3 = 0$

$\Lambda^0 \longrightarrow |0, 0\rangle$

Delta - Particle ($\Delta^{++}, \Delta^+, \Delta^0, \Delta^-$)

$2I+1 = 4$

$\therefore I = 3/2$

$-3/2 \le I_3 \le 3/2$

$\therefore I_3 = -3/2, -1/2, 1/2, 3/2$

$\Delta^{++} \longrightarrow |3/2, 3/2\rangle$

$\Delta^{+} \longrightarrow |3/2, 1/2\rangle$

$\Delta^{0} \longrightarrow |3/2, -1/2\rangle$

$\Delta^{-} \longrightarrow |3/2, -3/2\rangle$

(*) State Gellmann Nishjima Relation for Particles.

→ the charge of a Particle, $Q = I_3 + \frac{B}{2}$,

where, I_3 = Third component of isospin.

B = Baryon number.

Ex - for π^+, $I_3 = 1$, $B = 0$

$\therefore Q = 1$ (+, +ve charge of electron)

for Δ^{++}, $I_3 = 3/2$, $B = 1$,

$\therefore Q = 2$ (+, +ve charge of e^-)

Note:- This formula is not valid for hyperon's except delta.

Say, Σ^+, $I_3 = 1$, $B = 1$, , $Q = \frac{3}{2}$ (~~+ve charge of e⁻~~) (not hold)

(*) (i) what do you mean by strange particle.

(ii) write down the modified form of G.
Nishjima formula for strange particle.

→ (i) There are some particle's in nature which create via strong interaction but decay via week interaction, for this strange behaviour of these particles, they are known as strange particles.

For these particles we assign a new quantum number called strangerness (S).

(ii) the modified form of G. nishjima formula

$$Q = I_3 + \frac{B+S}{2}$$; S = Strangeness quantum no.

for, Σ^+ ; $1 = 1 + \frac{1+S}{2} \Rightarrow S = -1$

Σ^0 ; $0 = 0 + \frac{1+S}{2} \Rightarrow S = -1$

Σ^- ; $-1 = -1 + \frac{1+S}{2} \Rightarrow S = -1$

for, Cascade :- Ξ^- ; $-1 = -\frac{1}{2} + \frac{1+S}{2} \Rightarrow S = -2$

Ξ^0 ; $0 = \frac{1}{2} + \frac{1+S}{2} \Rightarrow S = -2$

for, omega, Ω^- ; $-1 = 0 + \frac{1+S}{2}$ $\Rightarrow$ $S = -3$.

for, Lamda, Λ^0 ; $0 = 0 + \frac{1+S}{2}$ $\Rightarrow$ $S = -1$.

K-meson :-

K^+ , $1 = \frac{1}{2} + \frac{0+S}{2}$ $\Rightarrow$ $S = 1$

K^0 ; $0 = -\frac{1}{2} + \frac{0+S}{2}$ $\Rightarrow$ $S = 1$

K^- ; $-1 = -\frac{1}{2} + \frac{0+S}{2}$ $\Rightarrow$ $S = -1$

$\bar{K}^0$; $0 = \frac{1}{2} + \frac{0+S}{2}$ $\Rightarrow$ $S = -1$

Q// (i) Draw meson octate and point out the position of different meson particles in the diagram.

(ii) Define Hyper charge?

→ (ii) The sum of Baryon number and strangeness number is known as hyper charge.

Hyper charge, $Y = B + S$.

(i)

Particle	I (iso-spin)	I_3	Q	B	S	$Y = B + S$
π^+	1	1	1	0	0	0
π^0	1	0	0	0	0	0
π^-	1	-1	-1	0	0	0
K^+	1/2	1/2	1	0	1	1
K^0	1/2	-1/2	0	0	1	1
$\bar{K}^0$	1/2	1/2	0	0	-1	-1
K^-	1/2	-1/2	-1	0	-1	-1
η^0	0	0	0	0	0	0

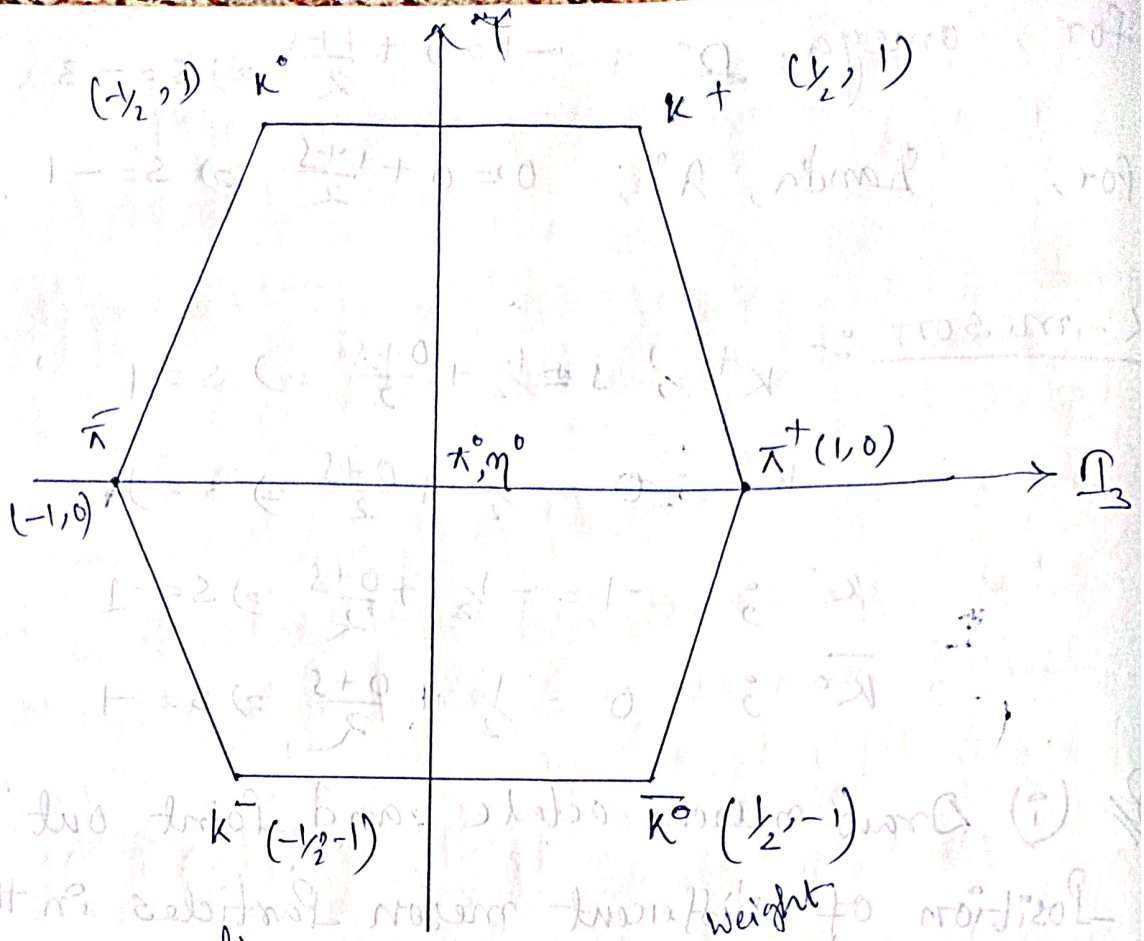


fig:- Meson octate 1 diagram.

⊛ Draw the baryon octate weight diagram?

Particle	I	I_3	Q	B	S	Y = B+S
p	$\frac{1}{2}$	$\frac{1}{2}$	1	1	0	1
n	$\frac{1}{2}$	$-\frac{1}{2}$	0	1	0	1
Σ^+	1	1	1	1	−1	0
Σ^0	1	0	0	1	−1	0
Σ^-	1	−1	−1	1	−1	0
Ξ^0	$\frac{1}{2}$	$\frac{1}{2}$	0	1	−2	−1
Ξ^-	$\frac{1}{2}$	$-\frac{1}{2}$	−1	1	−2	−1
~~Ω^-~~	~~0~~	~~0~~	~~−1~~	~~1~~	~~−3~~	~~−2~~
Λ^0	0	0	0	1	−1	0

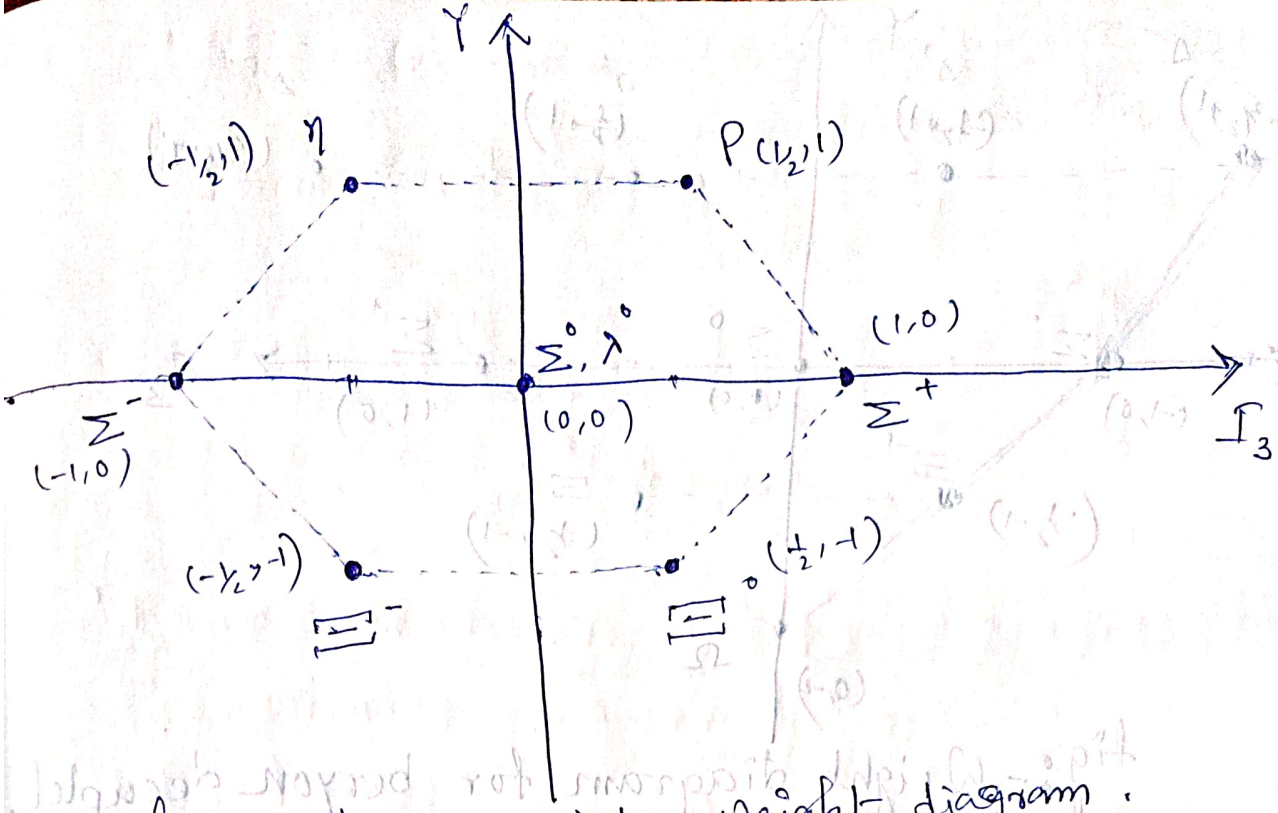


fig:- beryon octate weight diagram.

Draw the weight diagram for beryon decuplets (OR) Draw the weight diagram for resonance beryons?

→ the beryons which has spin $\frac{3}{2}\hbar$ in higher exited state is known as resonance beryons.

the resonance beryons has high energy.

Particle		I	I_3	Q	B	S	$Y = B+S$
Σ^+	——	1	1	1	1	-1	0
Σ^0	——	1	0	0	1	-1	0
Σ^-	——	1	-1	-1	1	-1	0
Ξ^0	——	1/2	1/2	0	1	-2	-1
Ξ^-	——	1/2	-1/2	-1	1	-2	-1
Ω^-	——	0	0	-1	1	-3	-2
Δ^{++}	——	3/2	3/2	2	1	0	1
Δ^+	——	3/2	1/2	1	1	0	1
Δ^0	——	3/2	-1/2	0	1	0	1
Δ^-	——	3/2	-3/2	-1	1	0	1

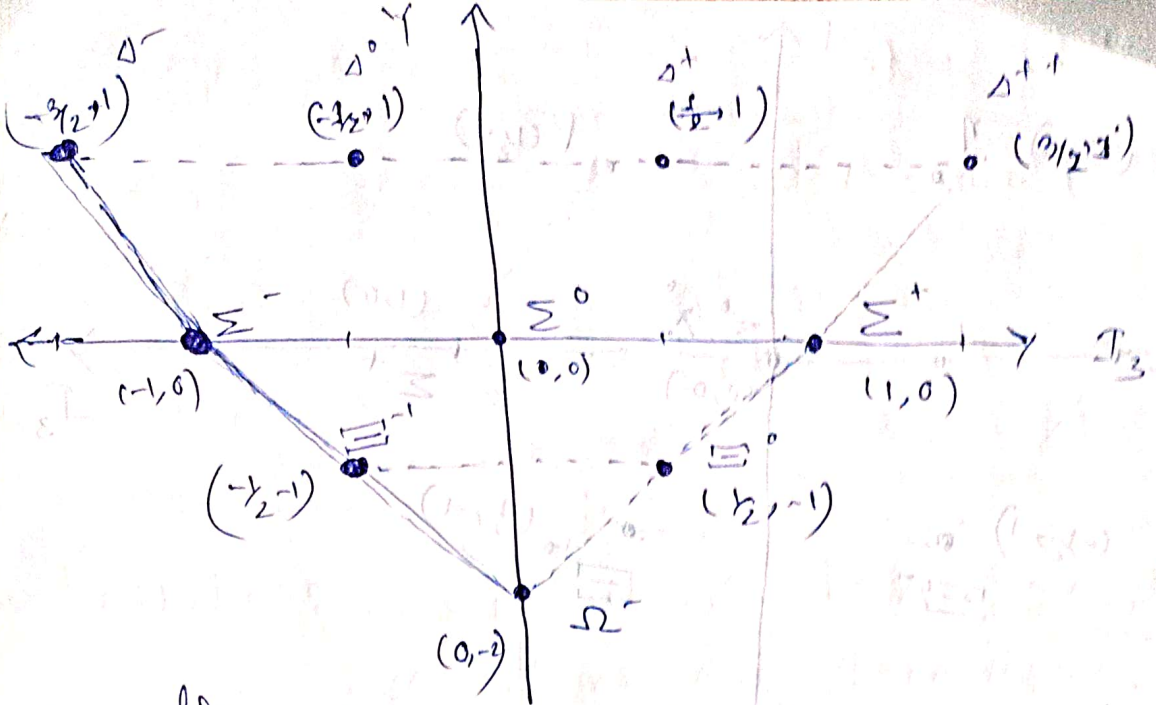


fig:- Weight diagram for beryon decuplet.

(*) (i) Write a short note on Quark model?

(ii) Write down the Quark's component of meson's and beryons?

(i) the meson's and the beryon's are made of fundamental Particle's known as quark's,

Quark's are basic unit's of Particle's.

there are 6 quark's and 6 anti-quark's the quark's Particle do not hold charge quantization.

Quarks	Symbol	charge	strangeness	Anti-qu
up	u	$2/3\,e$	0	$\bar{u}$
down	d	$-1/3\,e$	0	$\bar{d}$
strange	s	$-1/3\,e$	-1	$\bar{s}$
charm	c	$2/3\,e$	0	$\bar{c}$
top	t	$2/3\,e$	0	$\bar{t}$
bottom.	b	$-1/3\,e$	0	$\bar{b}$

(i) From the Experiment, the meson's are made of one quark and one antiquark. the beryon's are made of 3 quark's.

(ii) Quark components of beryon's :-

Name of beryon's	Quark Compment
p	uud.
n	udd.
Σ^+	suu
Σ^0	sud.
Σ^-	sdd.
Ξ^0	ssu.
Ξ^-	ssd
Ω^-	sss
λ^0	sud.
Δ^{++}	uuu.
Δ^+	uud.
Δ^0	udd
Δ^-	ddd.

[antiquark's have oposite sign of charges of quarks.

Quark component of meson :-

Name of Meson	Quark Component.
π^+	$u\bar{d}$
π^0	$d\bar{d}, u\bar{u}$
π^-	$d\bar{u}$

K^+	$\bar{s}u$
K^0	$\bar{s}d$
η^0	$d\bar{d}, u\bar{u}$
K^-	$s\bar{u}$
$\bar{K}^0$	$s\bar{d}$

(*) Note :- each quark's have spin $\frac{\hbar}{2}$, i.e they are fermion's.

(*) Write a short note on colour hypothesis of quark's.

→ the combination of quark's to form the baryons involves a serious problem of violation of Pauli's Exclusion Principle as similar kind of quark's with identical Q no. are present in the same particle.

For example - $n(udd)$, $p(uud)$, $\Delta^{++}(uuu)$ etc.

to avoid the violation of Exclusion Principle, each type of quark's are given 3-distinct colours (flabours) as red, green, and blue. [this colours have nothing to do with real colour]. This is known as colour hypothesis of quark's.

From colour hypothesis we get

18 quark's and 18 antiquark's.

(*) check if the following reaction's are allow or forbidden.

(i) $\pi^- + p \longrightarrow \lambda^0 + \pi^0$

(ii) $p + \bar{p} \longrightarrow 2\pi^+ + 2\pi^- + 2\pi^0$

→ (i) the reaction is electromagnetic reaction or strong interaction.

Q : $-1 \quad +1 \;|\; 0 \quad 0$

$= 0 = 0$, charge conserved.

B : $0 \quad 1 \;|\; 1 \quad 0$

$= 1 = 1$, Beryon no. conserved.

I : $1 \quad -\frac{1}{2} \;|\; 1$

$\frac{3}{2} \neq 1$, Isospin is not conserved.

So, this reaction is forbidden.

(ii) the reaction is electromagnetic or strong interaction.

Q : $1 + -1 \;|\; 2 + -2 + 0$

$= 0 = 0$, charge conserved.

B : $1 \quad -1 \;|\; 0 \quad 0 \quad 0$

$= 0 = 0$, Beryon no. conserved.

I : $\frac{1}{2} \quad \frac{1}{2} \;|\; 1 \quad 1 \quad 0$

$1 \neq 1$, Isospin is not conserved.

So, this reaction is forbidden.

so, this reaction is not possible.

:- Particle Accelerator :-

Q/ what is Particle accelerator. Why Particle accelerator is used.

→ Particle accelerator is a device used to accelerate different charge Particle's to high velocity or high KE, which is necessary for many nuclear reaction's or nuclear Experiment.

For Example :- in Rather-ford Experiment α-Particle's bombared or collide with gold attom's to check the exiestance of nucleus,

In this experiment, the KE of α-particle's was greater than 8 Mev.

Note :- In many nuclear reaction's, the projectil must have sufficient amount of KE to overcome the colomb force.

this can be done using Particle accelerator.

(*) classify Particle accelerator with Example?

→ there are basically two type's of Particle accelarator.

Accelerator

Electrostatic Particle accelerator.

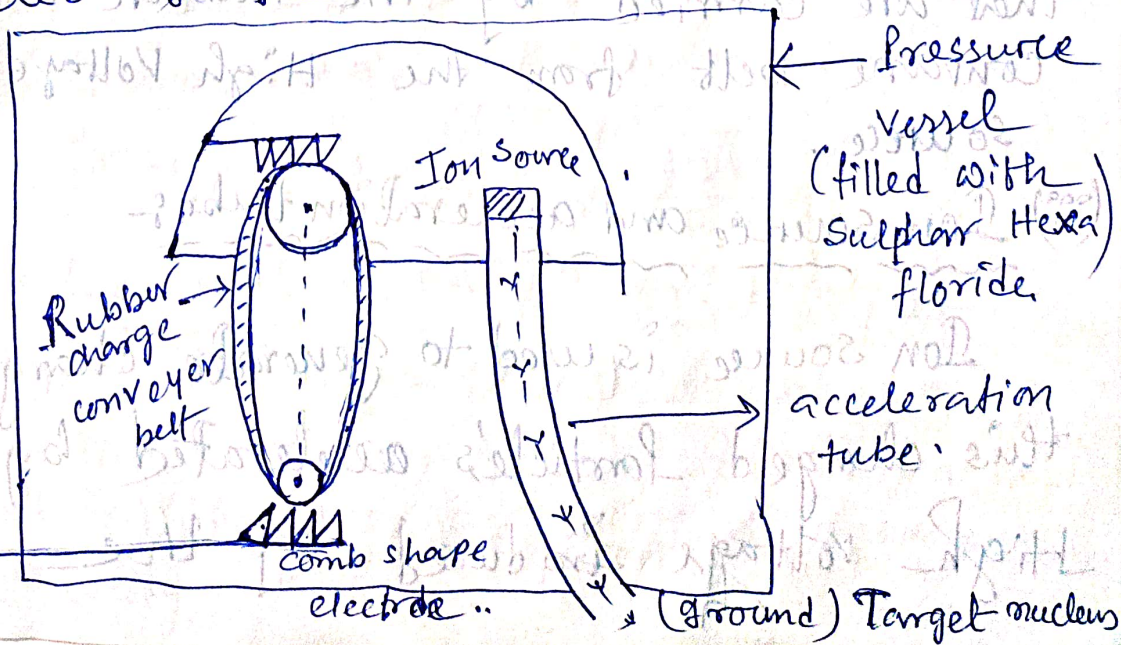
example —
(i) Vande graff generator.
(ii) Tandon accelerator.
(iii) Pelletron accelerator.

Electromagnetic Particle accelerator.

(i) Linear particle accelerator.
(ii) Betaton.
(iii) Cyclotron.
(iv) Synchroton.

(*) (i) Explain the working of Vande graff accelerator with proper diagram?
(ii) Write down the limitations of Vande-graff generator.
(iii) Write down the modification in Vande graff Generator to construct tendon and pelletron accelerator.

→ (i) Vandegraff genetor was discovered in 1929 by scientist van-de-graff. The modern day vande graff generator can accelerate Particle's to KE 5 Mev.



Construction :-

The main components of vandegraff generator are — (i) rubber charge convare belt and comb shaped electrode :-

A high voltage dc source is connected to a comb shape electrode, the comb shape electrode is choose for maximum transfer of charge as charge density is high at sharp edge, the rubber convare belt is used to carry the charge to the electrode which is connected to hemispherical hollow conductor. As we know that, the charge of a conductor always resides in the surface, the charge is transfered to the surface of the conductor, by comb shape electrode, As this Proces continue the charge on the conducting surface increase

(ii) Hollow hemispherical conductor :-

this conductor is used to store the charge that are carried by the Hubber charge convare belt from the High Voltage DC source.

(iii) Ion source and accleration tube :-

Ion source is used to generate charge Partic this charged Particle's accelerated by the High voltage produced by the

Hemispherical conductor. the accelerated ion/charge then pass through the acceleration tube and bombared with target nucleus. The target nucleus is at zero potential/ground.

Working formula :- As the charge on hollow hemispherical conductor increases the potential of hemispherical conductor increases. for any conductor potential inside the is uniform and equal to the potential at the surface.

at sufficient amount of charge let, the voltage or potential of the conductor is V.

the end of acceleration tube is connected to ground.

Let, the charge of ion is q.

Potential difference = (V-0) = V.

the KE gain by ion,

$$KE = qV$$

$$\Rightarrow \frac{1}{2}mv^2 = qV$$

$$\Rightarrow v^2 = \frac{2qV}{m} \Rightarrow \boxed{v = \sqrt{\frac{2qV}{m}}}$$

this is the expression for final velocity of accelerated ion or particle.

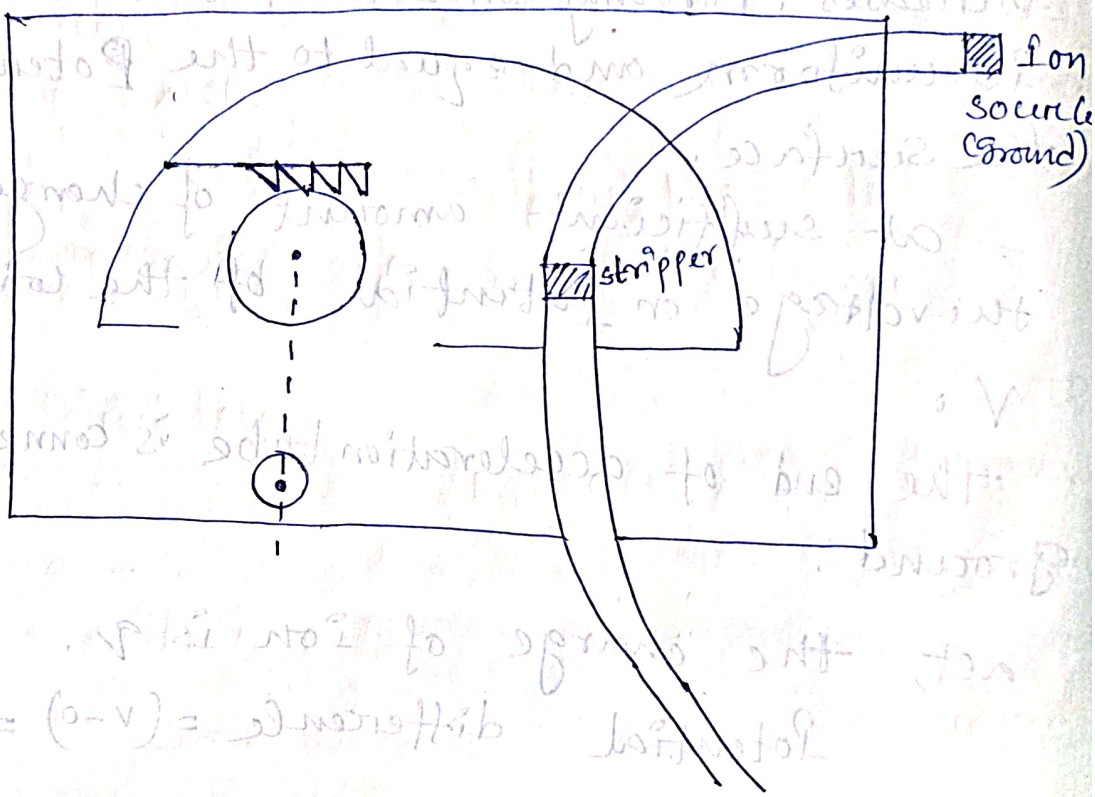
The final velocity directly depend's on the potential difference V. as the p.d. increases, the velocity increases,

Limitation of vandegraff generator :-

(a) By vande graff generator, we can accelerate +ve charge only.

(b) the charge particle can accelerate once, by van de graff Generator.

(iii) Tendon accelarator :-



In tendon accelerator, for high acceleration and extra accleration tube is used. 1st -ve charged ion's accelerated then by using stripper material the -ve charge is converted to +ve charge ion.

[carbon foil can be used as stripper material.]

In this case the KE gain by charge

Particle,

$$\frac{1}{2}mv^2 = qV + qV$$

$$\Rightarrow v^2 = \frac{4qV}{m}$$

$$\therefore v = \sqrt{\frac{4qV}{m}}$$

i.e. the final velocity of accelerated particle's increases by $\sqrt{2}$ times of vande graff generator.

Pelletron accelerator:-

Pelletron accelerator is similar to tendon accelerator but instant of rubere charge conrare belt achain of mattelic small cylindrical shells connected with each othere by nilon or any insulating material is used. This small omettelic cylinderis are known as pallet's, this pallet's can transfer more charge from the High voltage Ac source to the hollow hemispherical conductor, which Produces higher voltage and higher acceleration of charge particle.

(*) (i) Explain the linear Particle accelerator (LINAC)
(ii) Write down the limitation of linear particle accelerator?

→ (i)

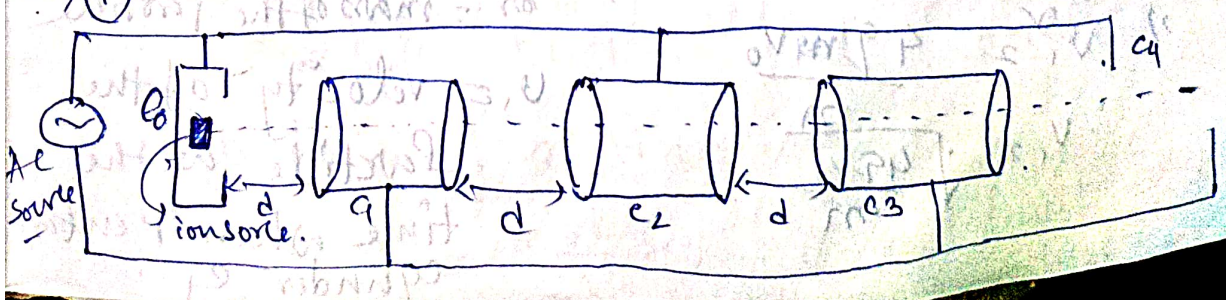


Fig:- Construction of Linear Particle Accelerator.

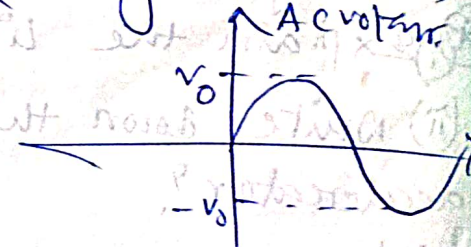
Construction:- Linear Particle accelerator consist of consiquitive co-axial mattelic cylindrical shell, the separation between two consiquitive cylindrical shell is const.

The cylindrical shell's connected to alternating voltage source such a way that if $c_1, c_3, c_5 \ldots$ are in +ve voltage then $c_2, c_4, c_6 \ldots$ are in -ve voltage. the ion source is with in the initial cylindrical shell as shown in the figure.

Working Principle:-

Let, a +vely charge Particle with charge +q emitted from the ion source with initial velocity = 0.

at the time the particle leaves to cylinder; $c_0, c_2, c_4 \ldots$ are in +ve volatage and, $c_1, c_3, c_5, \ldots$ are in -ve voltage. By using work-energy theorem,



$dW = dK$

$\Rightarrow q \cdot 2V_0 = \frac{1}{2} m v_1^2$

$\Rightarrow v_1^2 = \frac{4qV_0}{m}$

$\therefore v_1 = \sqrt{\frac{4qV_0}{m}}$

where, m = mass of the Particle

v_1 = velocity of the Particle at the time when it enters cylinder c_1.

The velocity of the charge particle will remain const. inside the cylinder C1, because inside the metallic cylinder the E. field is zero. and the potential is const. When the particle leaves the cylinder 4, the polarity of all the cylinder's should be changed to accelerate the particle. By using work-energy theorem,

$$q \cdot 2V_0 = \frac{1}{2}mv_1^2 - \frac{1}{2}mv_1^2$$

$$\Rightarrow 2qV_0 + \frac{1}{2}mv_1^2 = \frac{1}{2}mv_2^2$$

$$\Rightarrow 2qV_0 + 2qV_0 = \frac{1}{2}mv_2^2$$

$$\Rightarrow v_2 = \sqrt{\frac{8qV_0}{m}}$$

Similarly, $v_3 = \sqrt{\frac{12qV_0}{m}}$,

$$v_4 = \sqrt{\frac{16qV_0}{m}}$$

$$\vdots$$

$$v_n = \sqrt{\frac{4nqV_0}{m}}$$ [at the time of entering

the ratio of consequitive velocities cylinder, in

$$v_1 : v_2 : v_3 : \cdots : v_n = \sqrt{4} : \sqrt{8} : \sqrt{12} : \cdots : \sqrt{4n}$$

$$= 1 : \sqrt{2} : \sqrt{3} : \cdots : \sqrt{n}$$

Let, the angular frequency of the AC voltage source $= \omega$ and the time period $(T) = \frac{2\pi}{\omega}$

the particle should leave each of the cylinder, after time $T/2$.

$$\therefore \frac{T}{2} = \frac{l_n}{v_n} \quad [l_n = \text{length of } n^{th} \text{ cylinder}]$$

$\Rightarrow l_n = \frac{T}{2} v_n$

$$l_n = \frac{T}{2}\sqrt{\frac{4nqV_0}{m}}$$

$$l_n = T\sqrt{\frac{nqV_0}{m}}$$

the ratio of length of consicuitive cylinders

$$l_1 : l_2 : l_3 : \ldots\ldots : l_n = 1 : \sqrt{2} : \sqrt{3} : \ldots\ldots \sqrt{n}$$

the length of the cylinder's increases ~~constant~~ with the velocity of the particle increases, to maintain the synchronisation.

(ii) Limitation :-

(a) Linear Particle accelerator will take large amount of space. for high acceleration of Particle.

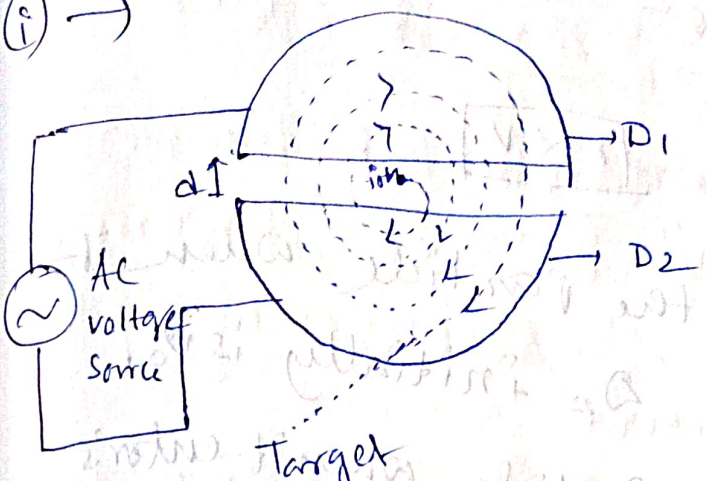
(b) If the velocity of the Particle reaches relativistic domain (velocity of the Particle nearly equal to velocity of light in vacuume), the linear accelerator will not work Properly.

(*) (i) Explain the working of cyclotrone.

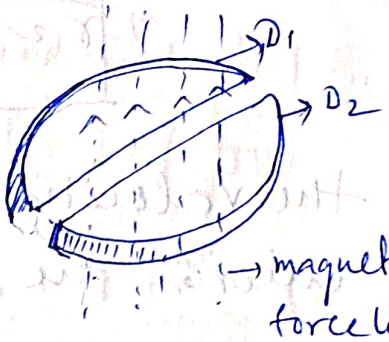
(ii) write down the advantage of cyclotrone over linear Particle accelerator.

(iii) write downe the limitation of cyclotrone.

(i) →



top view of cyclotron.



Side view of cyclotron.

Construction:- Cyclotron is consist of two half of a ~~dhola~~ hollow metallic cylindrical shell. the two half's are shown in the figure as D_1 and D_2. An external magnetic field is apply to the D_1 and D_2 perpendicular to the surface.

D_1 and D_2 is connected to an AC voltage source such a way that the polarity of D_1 and D_2 change's when the particle leave's D_1 and moves towards D_2 and vice versa. D_1 and D_2 is separated by a distance d.

Working principle:- Let, a particle with charge q emitted from the source with velocity v_0. As the angle between velocity and applied magnetic field is 90°. the motion of the particle is a circular.

We know, Magnetic force $= q\vec{v} \times \vec{B} = \frac{mv^2}{r}$

$\Rightarrow qvB = \frac{mv^2}{r}$

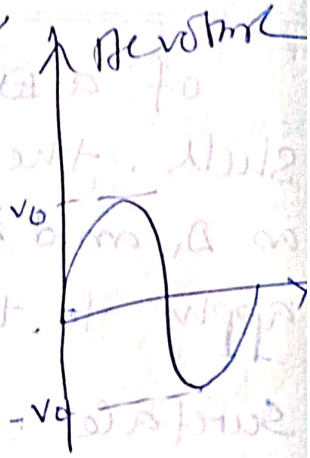
$\Rightarrow \boxed{r = \frac{mv}{qB}} \quad \boxed{r \propto v}$

the velocity of the particle when it enters the dice D_2 initially is v_0.

the velocity of the particle when it enters the disc D_1 for the first time $= v_1$

using work energy theorem,

$dW = dK$.



$\Rightarrow 2v_0q = \frac{1}{2}mv_1^2 - \frac{1}{2}mv_0^2$

$\Rightarrow 2v_0q + \frac{1}{2}mv_0^2 = \frac{1}{2}mv_1^2$

$\Rightarrow v_1 = \sqrt{\frac{4qv_0}{m} + v_0^2}$

the velocity of the particle is const. inside the metalic shell as the electric field is zero and the potential is const.

Let $v_2 =$ is the velocity of the particle when it enters D_2 for 2nd time.

Similarly using work energy theorem

$2qv_0 = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$

$\Rightarrow 2qv_0 + 2qv_0 + \frac{1}{2}mv_0^2 = \frac{1}{2}mv_2^2$

$\Rightarrow v_2 = \sqrt{\frac{8qv_0}{m} + v_0^2}$

$v_3 = \sqrt{\frac{12qv_0}{m} + v_0^2}$

:

$$v_n = \sqrt{\frac{4n q V_0}{m} + v_0^2}$$

the radius of the circular path

$$r_n = \frac{m v_n}{qB}$$

$$= \frac{m}{qB}\sqrt{\frac{4n q V_0}{m} + v_0^2}$$

i.e. the radius of the circular path increases with the velocity of the particle.

the time period of revolution, [independent of velocity]

$$T = \frac{2\pi}{\omega_n} = \frac{2\pi r_n}{v_n} = \frac{2\pi m}{qB}$$

for syncronisation of acceleration each particle leave disc after time $T/2$.

So, the angular frequency of the Ac voltage source = angular frequency of revolution,

$$\omega = \frac{2\pi}{T} = \frac{qB}{m} \quad f = \frac{qB}{2\pi m}$$

(ii) cyclotron will take less amount of space to accelerate a particle to a given velocity as compared to linear particle accelerator.

(iii) Limitation :- If the velocity of the particle reaches near about the speed of light in vacuum then it can not be applicable in relativistic domain.

(*) (i) Explaine the working Principle of synchrotron

(ii) What modification should be done in cyclotron to convert it to syntroton.

(iii) write down the advantages of Syntroton over cyclotron.

(ii) Syntrotone can accelerate Particle's to relativistic velocity to convert a cyclotron into syntrotone some modification should be needed.

We know that, angular frequency of revolution of the Particle,

$$\omega = \frac{qB}{m} = \frac{qB}{\frac{m_0}{\sqrt{1-v^2/c^2}}} = \frac{qB}{m_0}\sqrt{1-v^2/c^2}$$

m_0 = rest mass, V = Velocity of Particle

c = velocity of light in vaccume,

In relativistic domain the angular frequency of revolution decreases with the increase in velocity. But for syncronise acceleration, the angular frequency of Ac voltage source should be equal to angular frequency of revolution of the Particle,

this Synchronisation can be done in two way's —

(i) By decreasing the source frequency with the increase in velocity of the particle.

(ii) By increasing magnetic field with the increasing velocity. so that, the revolution frequency is remain const.

(iii) the advantages of synchrotron over cyclotron is ~~given by~~ this work in relativistic domain.